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EVALUATION OF THE SUITABILITY OF SKYLAB DATA FOR THE PURPOSE OF PETROLEUM EXPLORATION

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STATUS

Work is progressing well on S-190 data. S-192 tapes received and read to date (SL-2 and 3) are extremely noisy, at least in the channels examined. S-193 tapes were received this week and have not been examined. Most of the data originally requested has arrived. We have completed the review of the literature and are beginning to compile the geologic information extracted from the SKYLAB data and are beginning to compare it with other available data. The results of these efforts are described in the following sections entitled: Anadarko Basin, Comparison of Skylab Imagery and Aerial Photography, Comparison of the Results from Skylab and ERTS Imagery, and Inferred Lithology.

ANADARKO BASIN

General Description:

The Anadarko Basin occupies about 76,800 square kilometers in western Oklahoma and the Panhandle of Texas (Figure 1) and is bounded approximately by 34°45' and 37° north latitude and 97° 30' and 1`1° 30' west longitude. The basin was chosen as a test site because there is a great deal of published information available on the geology of the area, and many structures act as traps for hydrocarbons. The Anadarko Basin is also similar to several other large epicontinental sedimentary basins. In addition, the area was the site of Eason Oil Company's ERTS experiment.

Climate of the area ranges from moist sub-humid in the north and eastern parts of the area to semi-arid in the western part of the area. Rainfall ranges from one meter per year in the east to

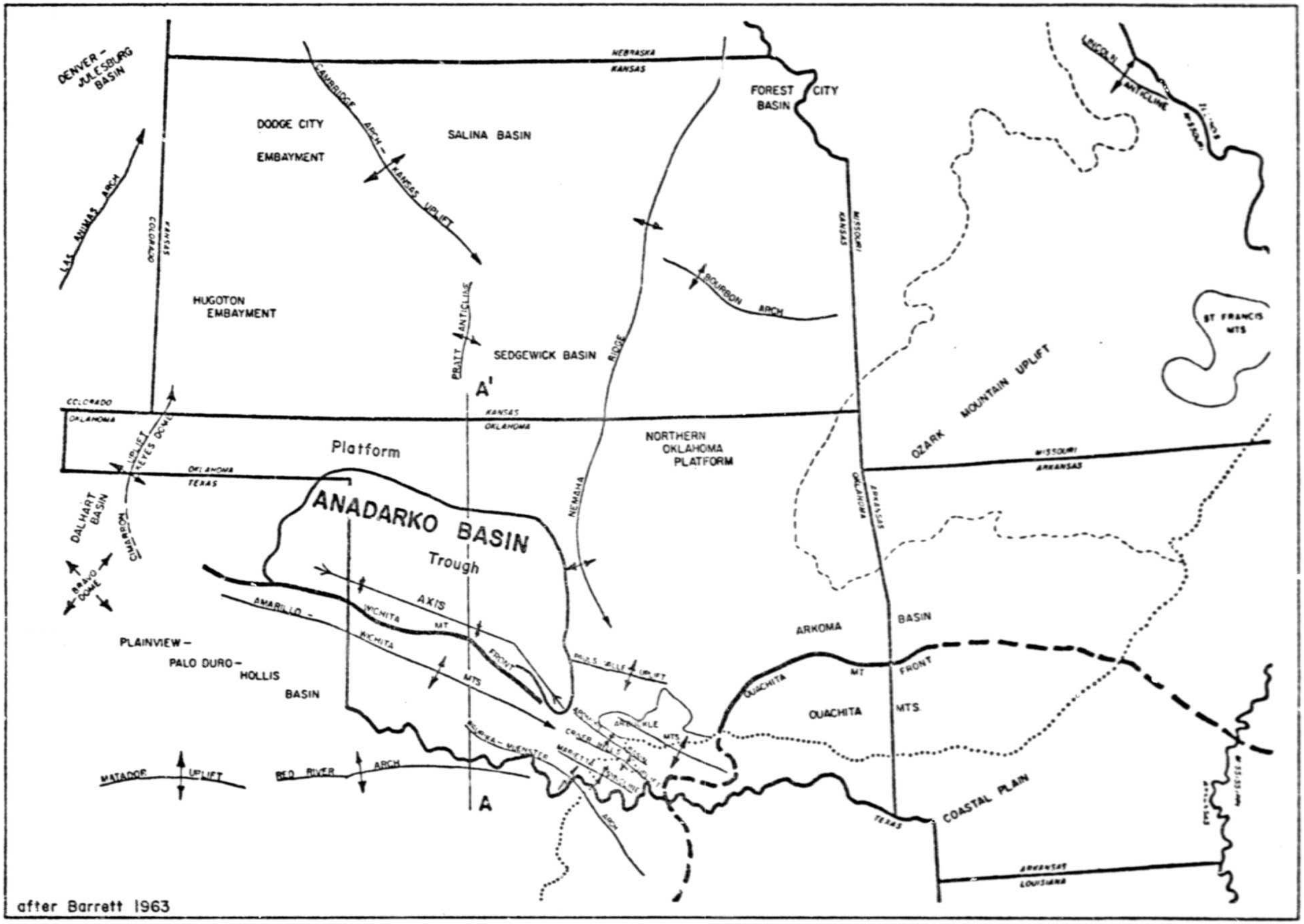


Figure 1. Regional setting of Anadarko Basin.

less than 40 centimeters per year in the far west. Consequently, native vegetation ranges from scrub oak in the east to short prairie grass and sage in the west.

Altitude to the surface steadily rises from 300 meters in the east to 1,500 meters in the west. Topography of the eastern part of the area is characterized by gently rolling hills with local relief of approximately 60 meters. In the west the topography is characterized by flat undissected uplands and mesas and deep canyons with local relief on the order of 350 meters.

The entire area is extensively farmed and ranched and most land holdings are divided along township and range survey lines. This imposes a north-south and east-west oriented cultural lineation over much of the area. Constancy of the pattern makes it easy to separate man-made linears from natural linears. Cultural features not parallel to this grid can be eliminated from interpretation by reference to USGS 1:250,000 scale topographic maps.

A second aspect of the extensive agricultural usage is that the tonal patterns produced by this vegetation and cultivated soil are imposed upon and replace native vegetation and undisturbed soils. Much of what one interprets is, in the final analysis, sensor response to vegetation and soils. Thus at some seasons of the year the cultivated vegetation tends to mask natural boundaries and at other times of the year it serves to accurately mark these boundaries.

Geology:

The following summary of the geology of the Anadarko Basin was derived from several sources, mainly Wheeler (1955), Huffman (1959), Eddlemen (1961), Cunningham (1961) MacLachlan(1964), Ham

et al. (1964), Petzel (1974) and Collins et al., (1974).

Location:

The Anadarko Basin trendswest-northwest from near Oklahoma City into Texas County, Oklahoma (Figure 1). The basin is bounded by the Nemaha ridge on the east, the Amarillo-Wichita-Criner Hills mountain chain on the south, the Cimarron uplift at the west end, and along the north by the Hugoton-Dodge City embayment and the Central Kansas uplift. The axis of the basin lies about 35 kilometers north of the Amarillo-Wichita uplift.

For the purposes of this study the Anadarko Basin is defined by the -3000 feet (-920 meters) structural contour (datum is sea level) on the top of the Mississippian MacLachlan, 1964). It can be divided into a platform and a trough. The trough is defined on the south by the frontal structural zone of the Amarillo-Wichita uplift. The -6000 feet contour (-1830 meters) on the Mississippian or the hingeline of Atokan deposition define the western and northern bounds. The Atokan hingeline and the -6000 feet contour approximately coincide. The hingeline is placed where thickening of sedimentary units increases from 10 ft./mile on the platform to about 50 ft./mile into the trough (Rascoe, 1962). The west-northwest trending axis of the basin lies near the south edge of the trough, giving the basin a strongly asymmetrical character (Figure 2).

Stratigraphy:

Layered basement rocks above the Precambrian substrate (1,100 and 1,350 million years old) total 7600 meters thick near the axis of the basin (Ham et al., 1964). They consist of late Precambrian

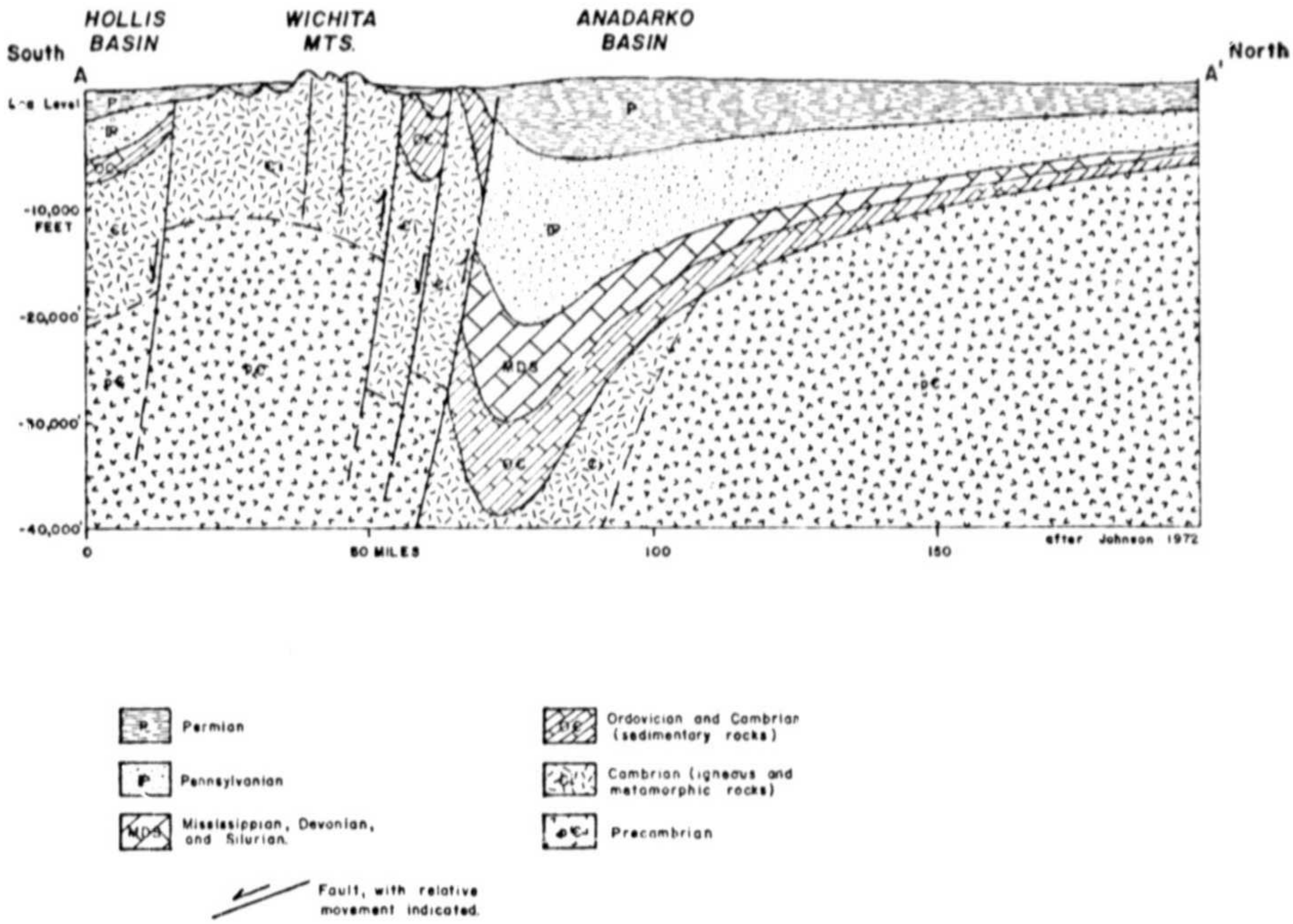


Figure 2. Cross section through the Wichita Mountains and Anadarko Basin showing asymmetry of the basin and the complex frontal structure composed of folds and high angle faults.

and early Cambrian metasedimentary rocks, early or middle Cambrian basalt and gabbro and late Cambrian granite and rhyolite.

Unconformably overlying the basement rocks is a series of sedimentary rocks representing every system from Cambrian through Quaternary. These rocks are as much as 11,500 meters thick near the axis. Paleozoic rocks thin northward onto the platform, being thickest in the present trough. Younger rocks reflect epeirogenic movements and distant orogenies and thus usually do not show thickening in the trough area.

Late Cambrian through Mississippian rocks are predominately limestone and dolomite. The first major hiatus in the record occurs in Devonian time at the end of Hunton deposition. The Hunton is unconformably overlain by the Devonian-Mississippian Woodford shale. Pennsylvanian through lower Permian rocks are predominately clastic rocks in the basin with limestones and dolomites interbedded in the shelf area to the north. The remainder of Permian rocks are clastic with significant thicknesses of interbedded evaporites.

Mesozoic rocks are limited to a few small exposures mostly on the periphery of the basin and are not of major concern to this study.

The Tertiary is represented by the Pliocene Ogallala formation composed of continental rocks that crop out over most of the area west and north of central Roger Mills County, Oklahoma.

Large areas on uplands and along major streams are covered by Quaternary wind-blown and stream-laid deposits.

Surface Rocks:

Cambrian and Ordovician rocks are exposed in the Wichita Mountains to the south of the Anadarko Basin, and isolated outcrops of Mesozoic rocks occur at several places (Figure 3).

Permian, Pliocene and Quaternary deposits are the most widespread surface units. Permian rocks are dominately shallow-marine, deltaic and alluvial deposits of red sandstone, shale and evaporite rocks. Gypsum and dolomite outcrops form conspicuous scarps. Thick salt units are widespread in the subsurface, affecting the surface by solution collapse and by local increases in salinity of surface and groundwater.

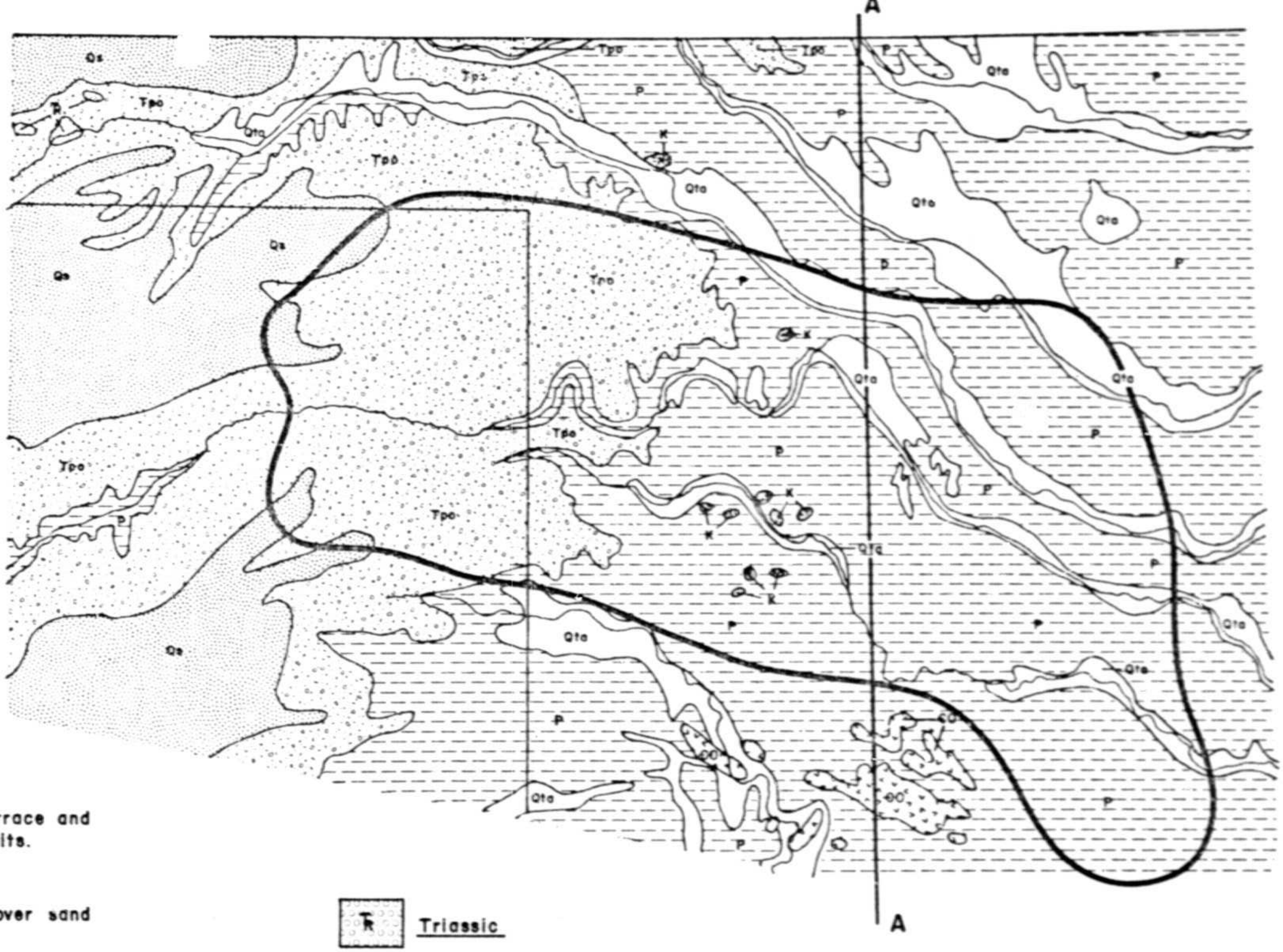
Pliocene Ogallala sediments are poorly consolidated, poorly sorted gravel, sand and clay with several layers of volcanic ash and bentonitic clay. Caliche occurs irregularly in the upper part of the exposed Ogallala.

Many upland areas in Texas and all major drainages are occupied by Pleistocene aeolian and fluvial deposits. Older deposits include sand, gravel and volcanic ash, whereas the younger are terrace deposits of gravel, sand, silt and clay with numerous channel deposits. Younger Pleistocene and recent dunes exist along several large streams and on some uplands. In addition, there are playa deposits in many small blowout depressions, particularly in the Pleistocene cover near Amarillo.

Tectonics and Geologic History:

In late Cambrian time, seas spread into the mid-continent from the Ouachita trough to the south. In the southern Oklahoma embayment Precambrian clastic rocks were reworked and deposited as the

Figure 3. Generalized Geologic Map Of The Anadarko Basin.



Qta — Quaternary: terrace and alluvial deposits.

Qs — Quaternary: cover sand on uplands

Tpo — Tertiary: pliocene, Ogallala formation.

K — Cretaceous

Ŧ — Triassic

P — Permian: redbeds, undifferentiated.

£O — Cambrian and Ordovician outcrops of Wichita Mtns.

0 10 20 30 MI
0 10 20 30 40 50 Km.

Scale: 1:2,000,000

(After Branson & Johnson, 1972)

Reagan Sandstone.

The embayment axis trended west-northwest from central Oklahoma to the Sierra Grande highland to the west. This axis was probably close to the present axis of the Amarillo-Wichita-Criner Hills uplift (Ham et al., 1964). Several areas of high relief affected sedimentation. Among these were Sierra Grande, "Llanoria" to the south and the central Kansas arch on the northeast. By the time of deposition of the Cambrian-Ordovician Arbuckle Group the crust in the vicinity of the present Anadarko Basin had developed into a broad sag. Minor structural adjustments caused thinning and local unconformities in units near the margin of the basin. This pattern of deposition continued essentially uninterrupted into mid-Devonian time. As the basin gradually subsided, the sea encroached on wider and wider areas during Simpson, Viola, Sylvan and Hunton deposition. Deposition was continuous near the center of the basin but was repeatedly interrupted on shelf areas.

The entire region was uplifted in middle Devonian time. Hunton and all older rocks were bevelled, particularly to the north and northeast, exposing Precambrian rocks in places. Wheeler (1955) suggests that the Amarillo-Wichita trend was already a positive feature.

The siliceous shales of the Devonian-Mississippian Woodford Formation accummulated on this irregular surface. Sedimentation continued uninterrupted throughout the Mississippian. At the end of Mississippian time, epierogenic uplift again occurred, seas retreated to the basin deeps, and the top of the Mississippian was eroded. Many features which later became prominent began to

develop as gentle folds and local warps. The Amarillo-Wichita arch was raised above sea level, separating the ancestral embayment into the Palo Duro-Hollis Basin on the south and the Anadarko Basin on the north. Late Mississippian or early Pennsylvanian Springer deposition, which was restricted to the deep part of the basin, was continuous with and in places overlapped by Morrow deposits.

The Anadarko Basin and the Amarillo-Wichita-Criner Hills uplift as they exist today, developed in late Morrow and Atoka time. This tectonic activity, known as the Wichita Orogeny, raised the Amarillo and Wichita Mountains along west-northwest trending high angle faults and developed a foredeep to the north creating the strong asymmetry of the Anadarko Basin. This fault system parallels older (pre-Mississippian) structural trends (Wroblewski, 1967) and consists of normal and high angle reverse faults.

The basin deepened rapidly during the Pennsylvanian period, marine deposition continued through Atoka and Des Moines time. Continued movement along older structures caused local thinning and onlap-offlap relationships within Atoka and Des Moines deposits. Coarse clastic rocks thin northward from the mountains, interfingering and grading into finer grained basin and shelf deposits.

A new system of faults developed that trend north 30° west, and cut older folds and fault systems (Wroblewski, 1967), These structures formed during a period of down-to-the-basin normal faulting. A third episode of Pennsylvanian tectonic activity produced faults that trend north 45° east. These faults cut other Pennsylvanian faults, but may have been active in the pre-Pennsylvanian (Wroblewski, 1967).

The importance and persistence of old structures is demonstrated by the Ft. Cobb, Cordell, Sayre and Mobeetie features. These are pre-Mississippian faulted anticlines trending northwest that were again deformed during Pennsylvanian time. According to Wroblewski (1967) these structures may even be Precambrian.

Taken as a whole, the Pennsylvanian sets of faults of different trends do not show a consistent relationship one to another. This suggests that several, if not all, of the sets of faults moved intermittently over the same period of time. The implication being that these simultaneously moving faults are the product of the same stress field.

Renewed orogeny in late Pennsylvanian time rejuvenated older structures but deformation did not extend as far into the Anadarko Basin as did earlier activity. Missourian and Virgilian deposition was widespread and continuous into lower Permian. Clastic rocks consistently grade into finer grained basin deposits toward the north. By late Pennsylvanian times all but a few high peaks had been covered by the deposits.

During Permian time the basin gently subsided. It became filled and land locked and great evaporite sequences accumulated.

Triassic and Jurassic deposits consist of isolated evaporites and terrestrial materials that accumulated in an arid upland. Little remains of Cretaceous rocks which may or may not have once covered much of the region. Apparently, the entire area was elevated and tilted to the east during the Laramide deformation to the west.

Tertiary activity consisted of minor warping and the accumulation of terrestrial deposits.

The area has been relatively quiet in Quaternary and Recent times. A variety of alluvial materials, gravels, and windblown sands are the dominant sediment types to the present.

COMPARISON OF SKYLAB IMAGERY AND AERIAL PHOTOGRAPHY

In order to establish the relationship of features seen in Skylab imagery to those seen in high altitude (RB-57) photographs, interpretations were made of an area near Marlow, Oklahoma. SKYLAB-4 , S190-B (Roll 94, No. 173) and high altitude color infrared photography (NASA Mission 105, Roll 18, Frame 6964) were compared. The original scale of the aerial photography is 1:110,000 and the interpretation of linear features prepared from the frame was reduced to the scale of the Skylab interpretation. The interpretations were overlayed and the coincidence of features noted on a separate overlay. Of the 174 lineaments interpreted from the Skylab image, 124 corresponded with features interpreted from the aerial photography.

Some 358 linear features were mapped on the aerial photography. However, the discrepancy in numbers of features is not as meaningful as appears at first glance. Because of the larger scale and higher resolutions, many features that were noted as a single line in the Skylab imagery were separated into two or more separate linears and counted as separate entities on the aerial photography. In addition, the synoptic view provided by the SL-4 imagery encouraged integration of many features that appeared separate and unrelated in the aerial photography. Consequently, one of the major differences in the two interpretations was the greater average length of features interpreted from the SL-4 photography. From the comparison, we conclude that there is a

surprisingly close correspondence between lineaments interpreted from SL-4 imagery and those seen in high altitude aerial photography, considering the differences in scale and resolution. Further, from the standpoint of regional analysis there are distinct advantages in using Skylab imagery over aerial photography alone.

COMPARISON OF THE RESULTS FROM SKYLAB AND ERTS IMAGERY

Lineaments interpreted from Skylab-3 S190A Imagery, Frame 113, Rolls 19, 20, 21, 22, 23 and 24 acquired on Track 48 in the vicinity of Elk City, Oklahoma were compared to composite lineament maps prepared from ERTS Spring and Fall imagery. The ERTS lineament maps were compiled from interpretation of all bands and color composites of imagery acquired on 8 October and 1 December 1972 and 1 March, 6 April and 24 April 1973. The comparison was made by reducing the compilation of Skylab lineaments to a scale of 1:1,000,000 and comparing it to compilation of lineaments detected in the ERTS imagery acquired in the Spring of 1973 and to a similar compilation prepared for imagery acquired in the Fall of 1972. Seventy-three features in the Skylab data that correlated to the Spring ERTS compilation were marked in purple. Those additional features (68) that correlated with lineaments in the Fall ERTS imagery were marked in red. Fall linears that duplicated the Spring linears are not indicated separately. Those features where red coincided with purple are marked as purple. Examination of the results indicate that about 50% of the Spring lineaments that coincided with the Skylab lineaments are oriented approximately N 45°E. The orientation of the correlative Fall lineaments is much more evenly distributed.

Within the area of comparison, that is the cloud free portion of Skylab Frame 113 (approximately 22,000 square kilometers), there were 461 lineaments mapped from the six bands of S190A Skylab imagery. Within the same area, there were 470 lineaments identified on the ERTS imagery. Of the 461 lineaments from Skylab, 141 corresponded (either coincided with or extended) the 470 lineaments mapped from ERTS. That is, approximately 30% of the lineaments mapped on the Skylab corresponded with ERTS lineaments. More importantly the trends of lineaments visible in the Skylab imagery correspond to those seen in the ERTS imagery. Lack of a more complete one to one correspondence of specific features is partially the result of different times of observations (time of day and almost a year apart), difference in resolutions and fundamental differences in the sensing system.

Detailed comparison of the results of interpretation of the two image types was performed only in this one area and for only one Skylab overpass. However, visual comparison indicate that approximately the same relationships hold true for other areas and for other Skylab overpasses. It is interesting to note that essentially the same number of lineaments were detected in both Skylab and ERTS imagery within the area of comparison. However, the ERTS map was the result of compiling essentially five complete coverages (4 bands plus color composites). Whereas the Skylab compilation consisted of the results from interpreting four black and white and two color images of a single Skylab frame. The similarity of numbers of features detected is probably more coincidental than meaningful.

We are presently acquiring ERTS imagery that at least approximates the dates and times of our SKYLAB passes. A more rigorous comparison of sensors and data can then be made.

COMPARISON OF INFERRED LITHOLOGY AND SURFACE GEOLOGIC MAPS

The general configuration of inferred lithologic boundaries interpreted from Skylab S190A imagery compare well with contacts on the Geologic Map of Oklahoma (1954) at a scale of 1:500,000. Most of the boundaries interpreted from Skylab imagery parallel but do not necessarily coincide with mapped stratigraphic contacts. However the agreement is much better for Skylab than ERTS imagery.

In the area chosen for comparison (Roger Mills, Custer, Dewey and Ellis Counties Oklahoma), S190A contacts as mapped from color images showed the best agreement. In particular, contacts interpreted from S190A, Roll 22, Frame 113 (color) agree well with the mapped Permian-Tertiary Ogalalla, Permian Doxey-Elk City, and Cloud Chief-Rush Springs contacts and some contacts of various Quaternary units. Boundaries mapped from the color IR, black and white IR and 0.5 to 0.6μ ("green band") show progressively less agreement.

The results of mapping inferred lithologic boundaries from S190B color imagery were even more impressive than those using the S190A imagery. In Oklahoma there was good agreement between interpreted and mapped boundaries between Quaternary and underlying Tertiary and Permian units, and boundaries separating the various Permian units (Rush Springs, Cloud Chief, Doxey and Elk City). There was excellent agreement between the interpretation and geologic maps on the Tertiary Ogallala-Permian contact.

In Texas the agreement was not as impressive at first glance, but in the area of comparison there are few strong lithologic contrasts. Areas of recent stream and dune deposits stand out clearly. Perhaps the most impressive aspect of the interpretation in this area is the presence of what appears to be a consistently identifiable boundary within the Ogallala formation. This raises the possibility that the Ogallala could be subdivided in the eastern Panhandle of Texas. Unfortunately however, the boundary was not obvious during preliminary field work in the area.

The conclusion drawn from the comparisons is that a methodology for rapid regional geological mapping can be developed based on the interpretation of S190B and, in some areas, S190A imagery. The methodology would include judicious field checking and ground sampling along with the study and interpretation of aerial photography and overflights in light aircraft.

RECOMMENDATIONS

None.

EXPECTED ACCOMPLISHMENTS

We intend to complete the experiment during the coming quarter. This will involve compilation and analysis of the interpretations already completed.

SIGNIFICANT RESULTS

Comparisons of the various photographic bands of Skylab imagery indicate that, overall, standard color (particularly S190B) is the most valuable for geological purposes. However, detailed

examination of all bands indicates that as with ERTS imagery each band contains useful information that is unique to it. Even with the poor resolution and extreme graininess of the IR bands, they showed important lineaments not seen in the other bands.

The results of geologic interpretations based on ERTS and Skylab imagery are strikingly similar. It appears that more information can be extracted from a single Skylab overpass than a single ERTS overpass, but that with repeated passes the lower resolution ERTS imagery may yield information comparable to that contained in S190B imagery. This again points up the importance of repeated coverage for geologic interpretation.

Comparison of Skylab photography to high altitude aircraft photography suggests that there are distinct advantages to using Skylab imagery for regional geologic interpretations. This is primarily because of the synoptic view provided by the space acquired imagery allows and encourages integration of regional geologic features.

Preliminary comparison of the geologic information interpreted from the Skylab imagery to existing geologic data suggests that faulting has played a much larger role in determining the morphology of the northern flank of the basin than previously assumed. The imagery reveals an abundance of long lineaments. Where these features have been checked in the field they are represented at the surface by joints, faults, or folds. In the few instances that we have been able to check these features against seismic data, they coincide with faults in the subsurface. Comparison of the interpretations to structural contours on subsurface units suggest that the lineaments can be correlated to

the morphology of the northern flank and western end of the basin.

REMAINING EFFORT

We anticipate completing the experiment in the next quarter. This work will include at least one more trip to the field, probably in mid-May.

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